**BELLCOMM, INC.**
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Extended LM Lunar Surface Mission Description - Case 232

DATE: September 28, 1967

FROM: N. W. Hinners

## ABSTRACT


A sample three day Extended LM (ELM) mission to the Flamsteed ring structure is presented. It is evident that the ELM concept provides the potential for increasing lunar exploration capability over that of Apollo. The full realization of that potential depends upon being able to land close (∿100 m) to points of specific interest and upon the availability of mobility aids.

The mission described is probably overly ambitious in that up to several more days could be profitably utilized at the site accomplishing the described tasks.

The exercise profited immensely from the availability of high resolution orbital photography. It is the author's opinion that such photography will be required for all realistic future mission planning and thus for all potential lunar landing sites.



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MEMORANDUM FOR FILE

## I. INTRODUCTION

The AAP Lunar Missions Ad Hoc Study Team has derived a baseline program for the early AAP lunar surface missions which commences with the Extended LM. The Extended LM (ELM) concept is based upon an assumption of the existence of growth potential in Apollo. That growth, expected to come from use of system margins, constraint relaxation, and flight profile modification, can be used in varying proportions to provide an increase over that available on Apollo in lunar surface stay-time, landing flexibility and accuracy, landed payload weight and volume, and in payload returned to earth.

The exact manner in which the growth is used will depend upon the specific landing site and upon the specific technological and scientific objectives. Prior to the determination of those, however, it is desirable to describe a hypothetical ELM mission for purposes of indicating the general nature of the operations and objectives which can be accomplished. This then provides a baseline from which deviations can be made, and from which real mission planning can proceed, when more facts, actual sites, and firm priorities become established. It is the purpose of this memorandum to present such a mission description.

## II. ASSUMPTIONS

The baseline ELM mission described herein is based in part upon the general objectives, stay-time, payload weights and payload equipment prescribed by the AAP Ad Hoc Lunar Study Team and pertinent subgroups. Those are supplemented with considerations previously discussed by the author.(1)

### Stay-time

We assume a three day lunar surface stay-time with two EVA periods per day and two astronauts out simultaneously. The stay-time extension is accomplished primarily with the aid of increased consumables and a solar panel power source which must be deployed manually exterior to the ELM.

Landing Sites

It is envisioned that a prime requirement(1) on ELM missions will be to land the ELM to within ∿100 meters of a preselected spot of particular scientific interest. It is assumed that this usually will mean landing near topographic irregularities much greater than those tolerated by Apollo and that some of the margin may be used for propellant to accomplish the landing. For this exercise a specific site near the Flamsteed ring has been selected which will be described in more detail later.

Descent Payload

The descent payload weight will be 1000 pounds and consist of the following:

| | |
|---|---|
| Two Lunar Flying Units (LFU) | 300 lbs |
| LFU Support Equipment | 30 " |
| Communications and Navigation | 50 " |
| Geological Equipment, Engineering Experiments, Science Stations, Sample Containers (3) | 380 " |
| Lunar Surveying System and Camera | 75 " |
| Hand-held Drill | 25 " |
| Spare PLSS (2) | 140 " |
| TOTAL PAYLOAD WEIGHT | 1,000 lbs |

It is assumed that the LFU's will operate using reserve plus residual propellants (700-1,000 lbs) from the LM descent stage. This implies that engineering changes will be made to the ELM in which case additional weight may be taken from the descent payload. There is uncertainty about the capability of the ELM to carry two LFU's and as to whether or not a 150 lb LFU has a rescue capability. These considerations have obvious effects on overall mission effectiveness.

Ascent Payload

The ascent payload will include 100 lbs of lunar rock and/or soil samples.

## III. OBJECTIVES

The broad objective of all ELM missions is to extend the basic Apollo lunar exploration capability and to develop new exploration techniques. A given ELM mission will further consist of a mix of site-dependent and site-independent objectives. The former will be primarily geological in nature while the latter will be primarily geophysical and technological. The site-dependent objectives can be best dealt with if one works with a real lunar site.

### A. Site-dependent--Lunar Geology and Processes

The site selected for study and mission description is in the northern part of the Flamsteed P or Flamsteed ring structure (1° 40' S, 42° 59' W). This site was chosen for the reason that it is a scientifically interesting site for which high resolution (∿1 m) Orbiter photography is available and which shows enough variety of features to warrant an ELM mission. The objectives at this site will become apparent in the ensuing site description and presentation of the hypotheses concerning the origin of the observed features.

The Flamsteed ring is a discontinuous, roughly circular structure of about 100 km diameter, the northern section of which is shown in the medium resolution (∿8 m) photograph taken on the Orbiter I mission (Fig. 1). In this region the ring appears, topographically, as a series of ridges up to ∿300 m in elevation while internally concentric with it is a series of "typical" mare ridges up to ∿100 m high.[2] Of additional interest are the convex scarps or benches which bound the main ridge structures and the "patterned ground" texture on both ridges and scarps. One school of thought (see, e.g., Ref. 2), interprets the ring structure as a partially buried crater rim and the patterned ground and benches as an expression of down-slope soil movement (mass wasting). Another school[3,4] believes that the structures are the volcanic surface expressions of a large ring dike. If the former are correct, the mare should be younger than the ridge while the converse holds if the ring is an extrusive lava. A prime objective of the ELM mission is thus to investigate the structure in-situ, to observe structural and textural relationships and to sample the material at the ridge-mare contact.

From this, one may ascertain relative ages and composition, and determine the role of soil movement in producing patterned ground.

On the high resolution (∿1 m) photograph of the ring (Fig. 2), one can observe more of the patterned ground on the mare proper as well as numerous craters with a range of morphologies and rock distributions. It has long been assumed that the sharper, rock strewn craters are younger than the rock-free, more subdued or "eroded" appearing craters.* Radioactive age dates on samples from the different types of craters should shed light on the validity of this hypothesis as should in-situ geologic observation. Coincidentally, in Figure 2 one sees evidence for an alternative to the erosion hypothesis, for in that figure there appear two distinct types of mare surface. Nearer the ridge, in the vicinity of "A", the mare appears to have a lower density of small, fresh craters relative to the mare in the southwest corner of the photograph near "B". Separating the two regions is mare surface with well developed patterned ground. It is herein suggested that the region near "A" has been catastrophically rejuvenated at some point in the past relative to the surface southwest, destroying most small craters (∿50 m). Such an event, be it an overlay of a sheet of material such as volcanic ash, a blanket of crater ejecta, or some other phenomenon, has been hypothesized for other lunar areas. At this site in Flamsteed one can test the hypothesis directly.

Of additional scientific interest is the apparently fresh impact crater on a steep slope at "C" which shows preferential ejection of lunar material in the down-slope (southward) direction.

At "D" is an arcuate string of rocks which appears to extend almost to the foot of the ridge. Not obviously associated with a crater, this rock moraine presents an enigma. It is possible that it resulted from down-slope rock and soil movement, on the one hand, or by a process analagous to terrestrial frost-heaving. In-situ observations may allow solution of this problem.

B. <u>Site-independent</u>

The following objectives are essentially site independent in that what one does will not vary greatly as a function of the site. We realize, however, that how one accomplishes the objective may be a function of the site.

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*One must keep in mind the fact that small craters which do not penetrate the granulated layer will be initially rock-free.

1. Deploy a Scientific Monitoring Station

It is assumed that this will continue to be a useful function on many of the AAP lunar missions. The inherent advantages over Apollo are that there will be sufficient time to conduct a site survey prior to station deployment, time and weight available to deploy more experiments, and time to conduct functional tests, with fixes (if feasible), prior to ELM ascent.

2. Utilize an LFU in Lunar Exploration

A pressing desire for post-Apollo missions is an increase in mobility. This mission, assumed to be the first with an LFU, places emphasis upon test of the LFU. In addition to saving time and astronaut energy, one is able to conduct a better lunar exploration by going to locations inaccessible to an astronaut on foot.

3. Use Reserve and Residual Propellant for the LFU

It seems probable that 500-1000 lbs of propellant is desirable in order to make it worth carrying an LFU. Since it is impractical to carry that as payload on an ELM mission, we must depend upon successfully retrieving and using propellant remaining in the LM descent tanks both as reserve (available to the LM engine) and residuals (that trapped in lines and tanks which is unavailable to the LM engine).

4. Utilize Surface Back-pack Change to Increase Exploration Efficiency

Astronauts are now constrained to traveling only a short distance from the LM for two reasons - the Portable Life Support System (PLSS) energy capacity allows a nominal three hour EVA while the emergency oxygen supply dictates a maximum time (thus distance) from the LM of about 25-30 minutes. The ability to use a second and even a third PLSS on the lunar surface without the necessity of entering the LM for a recharge results in greatly extended surface range and operating time.

5. Test Surface Communications

One of the unknowns of lunar surface exploration is the ability to communicate when out of line-of-sight. It is possible, however, that communications can be effected through the lunar surface material. It is thus proposed that such be attempted in a series of tests whereby one astronaut slowly proceeds out of line-of-sight either by walking behind hills or boulders or by entering shallow craters.

### 6. Determine Ability to Conduct High Energy Tasks

Simulations of lunar missions are not thought to be effective with regard to metabolic expenditures. It is thus probable that one will have to slowly increase the load on astronauts during real missions in order to determine the limitations. The Flamsteed site provides several areas (ridges and craters) where it would be beneficial, scientifically, for an astronaut to climb for purposes of observation and sampling and where, with close monitoring of energy expenditure, one could conduct meaningful metabolic tests.

## IV. MISSION PROFILE

The activities envisioned for the six EVA periods are shown in Figure 3-5 and correspond to exploration at the site shown in Figure 2. The activities, occurring as far as 2 1/2 km from the touchdown point, are essentially self-explanatory in view of the previous text, but several remarks are pertinent relative to sequencing, allotted times, and distance from the ELM.

In general, highest priority tasks are conducted first as are those which are known from past experience to be assured of success. ALSEP deployment is delayed until after some geological investigation in order to optimize its location. It is not left until the end, however, in order to allow for redeployment.

The LFU's are new exploration tools. Therefore, we envision an extensive check-out period with many stops and a lot of hovering close to the ELM, which accounts for the large amount of time and propellant used. Further, there will be extreme conservatism exercised in both distance covered and velocity utilized on early missions. No flight has been made beyond walk-back distance and no flight would be made to the ridge top until the stability of the ridge soil was assured. It is assumed that any time one astronaut is using an LFU, the other remains near the ELM with a second LFU available for rescue.

About one-half hour has been allotted for specific sampling sites, a time interval not overly long for purposes of sampling, observing, photographing and describing.

## V. SUMMARY

A sample three day Extended LM (ELM) mission to the Flamsteed ring structure is presented. It is evident that the ELM concept provides the potential for increasing lunar exploration capability over that of Apollo. The full realization of that potential depends upon being able to land close ($\sim$100 m) to points of specific interest and upon the availability of mobility aids.

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Attachments:
  References
  Figures 1-5

BELLCOMM, INC.

## REFERENCES


1. Hinners, N. W., "Margin Allocations on Extended LM Lunar Missions," Memorandum for File, Bellcomm, Inc., June 9, 1967.

2. Lunar Orbiter Photo Data Screening Group, "Preliminary Geologic Evaluation and Apollo Landing Analysis of Areas Photographed by Lunar Orbiter III," Langley Working Paper 407, Langley Research Center, June 1967.

3. O'Keefe, J. A., P. D. Lowman, Jr., and W. C. Cameron "Lunar Ring Dikes from Lunar Orbiter I," Science 155, No. 5758, p. 77-79, January 6, 1967.

4. Fielder, G., "Volcanic Rings on the Moon," Nature, 213, No. 5074, p. 333-336, January 28, 1967.

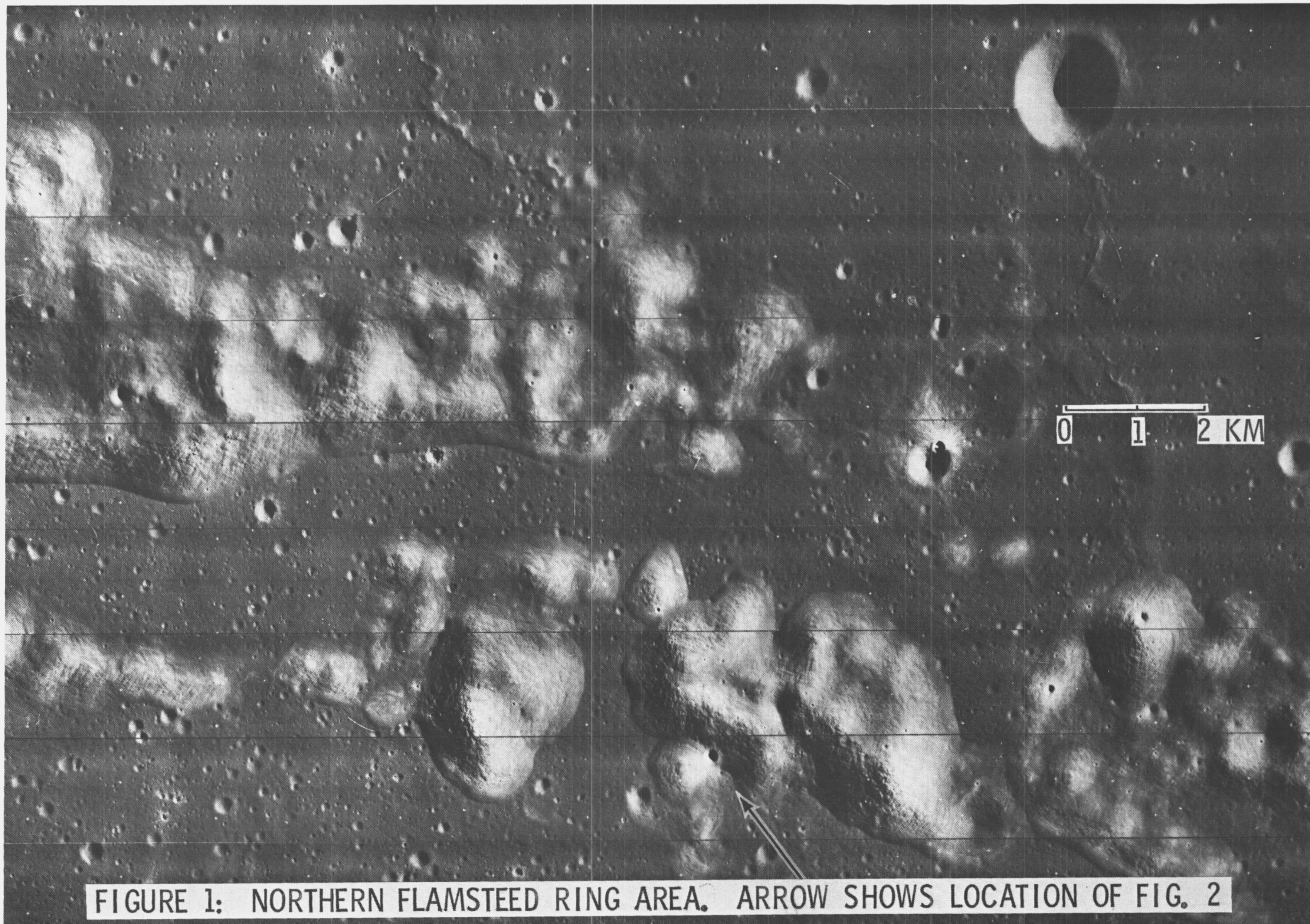


FIGURE 1: NORTHERN FLAMSTEED RING AREA. ARROW SHOWS LOCATION OF FIG. 2

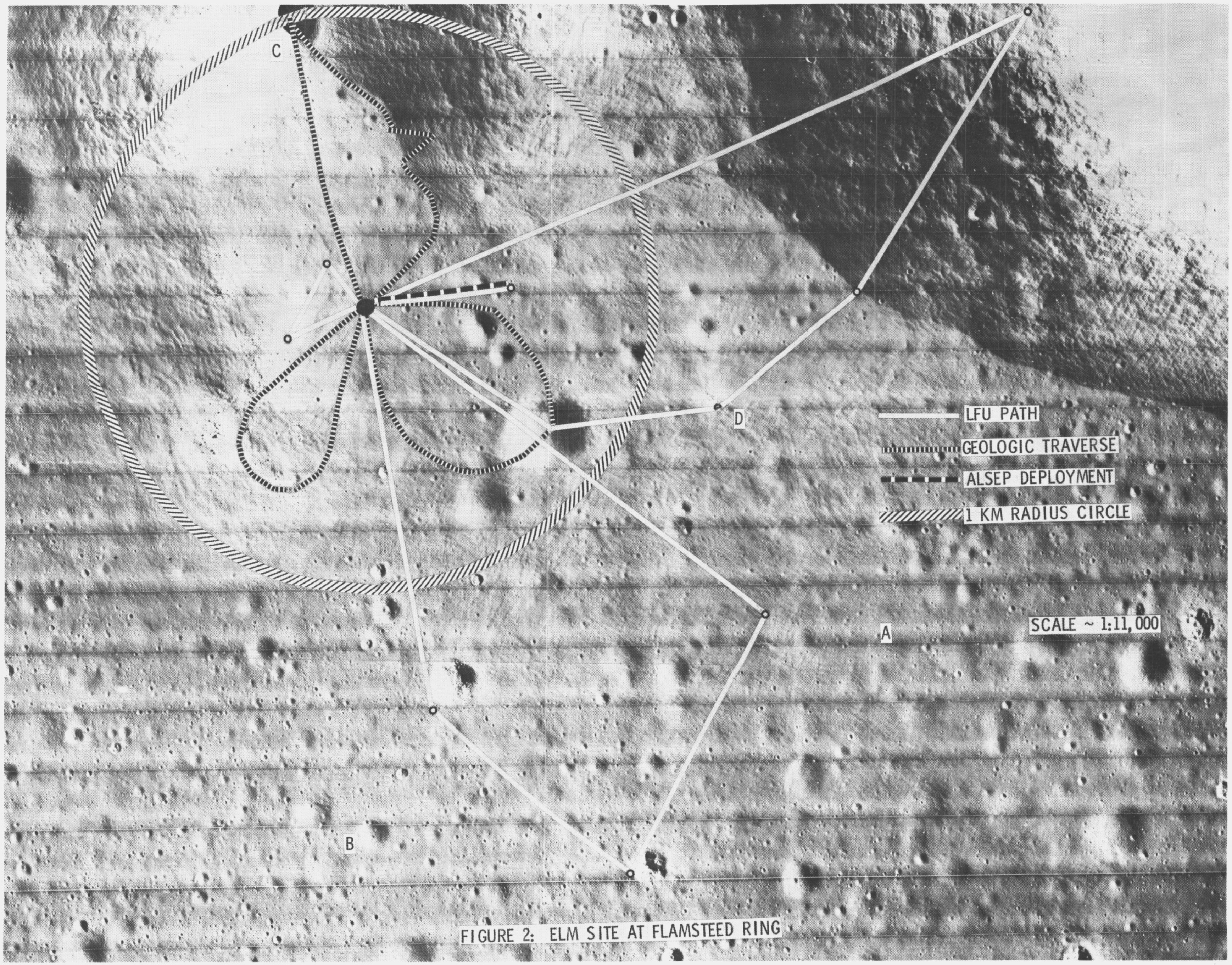


FIGURE 2: ELM SITE AT FLAMSTEED RING

1. INSPECT LM

UNLOAD EQUIPMENT

DEPLOY EXTENSION EQUIPMENT (SOLAR PANELS, ETC.)

CONDUCT SHORT GEOLOGIC TRAVERSE THRU ROCK-FIELD (EJECTA?)

SAMPLES "FINES" AND LARGE ROCKS

PHOTOGRAPH AND INVESTIGATE SURFACE TEXTURES

TEST OUT-OF-SIGHT COMMUNICATIONS

2. RIDGE-MARE TRAVERSE

PROCEED TO RIDGE-MARE CONTACT

EXAMINE STRUCTURAL AND TEXTURAL FEATURES

SAMPLE FOR COMPOSITION AND AGE DATING

CONDUCT SHORT CLIMB ONTO RIDGE

STUDY MATERIAL MOVEMENT AND SAMPLE

WATCH METABOLIC RATES

PROCEED TO IMPACT CRATER

OBSERVE EJECTA PATTERNS

SAMPLE

RETURN TO LM WITH SEQUENTIAL SAMPLING OF EJECTA

FIGURE 3: PROFILE FOR EVA 1 AND 2

3. LFU ORIENTATION + ALSEP DEPLOYMENT

FUEL LFU's

CONDUCT LFU ORIENTATION NEAR LM

REFUEL LFU's

"A" - FLY LFU WITH EQUIPMENT TO ALSEP SITE

SURVEY SITE

"B" - CARRY OUT ALSEP

DEPLOY ALSEP

FUEL: 10 STOPS

10 KM

400 LBS

4. LFU RIDGE TRAVERSE

"A" 1. FLY TO RIDGE CREST (WITH DRILL AND SAMPLE CONTAINERS)

2. MARE-RIDGE CONTACT

3. ROCK MORAINE, TEXTURE

4. "ERODED" CRATER INTERIOR

FUEL: 5 STOPS

6 KM

125 LBS

"B" REMAIN NEAR LM WITH LFU #2

DETAILED OBSERVATIONS

SAMPLE PREPARATION

FIGURE 4: PROFILE FOR EVA 3 AND 4

5. <u>LFU MARE TRAVERSE</u>

REFUEL LFU (DRILL + SAMPLE CONTAINERS)

"B" 1. FLY TO "OLDER" MARE

2. CRATER WITH SLUMP MATERIAL

3. PATTERNED MARE

FUEL: 4 STOPS

5 1/2 KM

105 LBS

"A" REMAIN NEAR LM WITH LFU #1

CONDUCT DETAILED OBSERVATIONS,

SAMPLING, AND ENGINEERING TASKS

ADJUST ALSEP IF NECESSARY (AND FEASIBLE)

PREPARE SAMPLES

6. <u>FINAL EVA</u>

CONDUCT SURFACE TRAVERSE EITHER TO

NEW AREA OR REVISIT AREA OF INTEREST

SWITCH-OVER PLSS ON SURFACE

PREPARE SAMPLES FOR RETURN

FIGURE 5: PROFILE FOR EVA 5 AND 6